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(19)

(54) IMPROVEMENTS IN OR RELATING TO VISIBILITY MONITORING APPARATUS FOR AIRFIELDS

(71) We, CIVIL AVIATION AUTHORITY, Directorate of Communications and Navigation, of Space House, Kingsway, London, a British Corporation established by statute do hereby declare this invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to visibility monitoring apparatus for airfields.

It is an object of the present invention to provide airfield equipment to aid aircraft landings in conditions of mist or fog.

According to the present invention there is provided apparatus at an airfield comprising:

a main visibility sensor arranged to monitor and to produce an output representing the visibility in a prediction area in the vicinity of the touchdown end of a runway;

one or more auxiliary visibility sensors arranged to monitor and to produce outputs representing the visibility in respective regions disposed about the prediction area;

wind sensors arranged to monitor and to produce respective outputs representing the wind velocity in the neighbourhood of the prediction area;

and computer means connected to receive the outputs of the main visibility sensors, the auxiliary visibility sensors, and the wind sensors and arranged to derive therefrom predictions of the visibility in the prediction area;

the disposition of the visibility sensors being such that in the wind velocity monitored, their distances from the prediction area gives a prediction period substantially between five minutes and thirty minutes.

In a situation in which wind is predominantly from one direction there may be a single auxiliary visibility sensor positioned upwind of the prediction area or a group of auxiliary visibility sensors disposed generally upwind of the prediction area. In such a case the apparatus will not provide any reliable prediction when the wind blows from a sufficiently different direction from its predominant direction.

The auxiliary sensor or sensors may be movable from one site to another so that they can be placed in upwind positions, the positions of the sensors being entered into the computer means. Alternatively the auxiliary sensors may be disposed all around the prediction area so that there is always one or more of them upwind of the prediction area whatever the direction of the wind.

The auxiliary sensors may be substantially equidistant from the prediction area, but preferably, to cope with a greater range of wind speeds, they are disposed in groups, the sensors in each group being substantially equidistant from the prediction area but those in different groups being at different distances from the prediction area. For example the auxiliary visibility sensors may be disposed in two concentric circles about the prediction area.

In addition to the visibility and wind sensors there may be temperature humidity and pressure sensors arranged to produce signals representing the temperature humidity and pressure in the neighbourhood of the prediction area, the computer means being connected to receive these signals and to predict changes in visibility due to dispersal or forming of mist or fog.

The computer means may be a single computer connected to receive the signals from the sensors via suitable interfacing or it may comprise a controlling computer and a plurality of dedicated computers, each of the dedicated computers being connected to receive signals from a respective set of sensors and and arranged to sample the signals and to compute necessary averages and variations, and the controlling computer being arranged to receive the computed averages and variations from the dedicated computers and to compute therefrom predictions of visibility in the vicinity of the touchdown area and an indication of the reliability of the predictions.

Measurements of visibility at airfields have shown that during periods in which the visibility

is generally too low for a landing to be made safely owing to mist or fog there are clearer periods in which the visibility is adequate for a landing. The visibility in fact is not constant but fluctuates. The clearer periods are often long enough for a landing to be made if an aircraft happens to be suitably positioned to make a landing but not long enough for an aircraft to get into position and then land. With apparatus according to the present invention, when the weather conditions are such as to allow reliable predictions, the occurrence of the clearer periods can be predicted in advance. Using this information the pilot of an aircraft wishing to land can arrange his aircraft so that he is in a position to make a landing at the time when a clearer period is predicted. If the clearer period does in fact occur he can then land.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings of which:-

Figure 1 shows, in schematic plan view, the arrangement of sensors in one embodiment of the invention,

Figure 2 shows an arrangement of computers in the embodiment of Figure 1, and

Figures 3 and 4 are flow diagrams illustrating how the predictions of visibility are made.

In Figure 1 there is shown the touchdown end of a runway 1. The area 2 between the runway threshold and the touchdown point (the prediction area) is shaded in the Figure. Adjacent to the prediction area 2 and displayed laterally out of the path of landing aircraft is a transmissometer 3 which forms the main visibility sensor. Point visibility sensors 4, sixteen in number in the Figure, constituting the auxiliary sensors, are disposed at regular intervals on a circle centred on the middle of the prediction area 2. The radius of the circle is chosen to give a suitable prediction time with the wind speeds normally encountered in foggy conditions. This will vary to some extent from one location to another, but since wind speeds over ten knots are conducive to fog dispersal and very low wind speeds are not conducive to fog formation a radius of about one kilometre, which will cope with wind speeds between about one and seven knots, will be suitable for most locations. To cover a wider range of wind speed two concentric circles of sensors can be used.

Wind sensors 5, capable of measuring wind speed and direction, are positioned at each of two locations within the circle of auxiliary sensors. All the sensors, so far as is compatible with aircraft safety, are the same height, about five metres, above the ground.

Figure 2 shows three dedicated microcomputers 6, 7 and 8. The computer 6 is connected to receive data from the wind sensors 5 of Figure 1 and is arranged to calculate the mean wind velocity and the variation of wind velocity, which gives a measure of gustiness and hence unpredictability. The computer 7 is connected to receive data from some of the visibility sensors and the computer 8 is connected to receive data from the rest. The computers 7 and 8 are arranged to calculate short-term averages of the visibilities at each of the sensor locations so as to smooth out very short term fluctuations. The visibility sensors are shared between two computers 7 and 8 for the sake of speed. A controlling computer 9 is arranged to synchronise and interrogate the dedicated computer 6, 7 and 8 and to compute predicted visibilities as will be explained later. A display unit 10 is provided to display the predicted visibilities and error warnings produced by the controlling computer 9.

Figure 3 illustrates how the predicted visibilities are calculated by the computer 9 of Figure 2. At the start of the program variables are given initial values (step 11). The computer then waits until it is time for a sample to be taken (step 12). Samples are taken at predetermined intervals, such as one second. The wind data are then fetched (step 13) from the dedicated computer 6 of Figure 2. If the wind data indicate that the wind is too gusty, or the mean wind speed is too high or low for prediction to be reliable, according to some predetermined criteria (step 14) an error warning is given (step 15). From the mean wind direction a sensor S is selected (step 16) from the auxiliary visibility sensors, which is upwind of the prediction area. If there had been two circles of sensors the sensor S would have been chosen from the appropriate circle on the basis of the wind speed. From the mean wind speed and the distance of S from the prediction area, the prediction period is calculated and added to the current time T to give the prediction time PT(N) (step 17). N is a counting variable which has been given the initial value of unity. The short-term average visibility corresponding to S is then fetched from the appropriate one of the dedicated computers 7 and 8 and is stored as V(N) (step 18). A correction term K, which has been given the initial value of zero, is then added to V(N) to give the predicted visibility PV(N) (step 19). The prediction times PT(N) and predicted visibilities PV(N) are displayed (step 20) and the computer then proceeds with the steps illustrated in Figure 4.

Figure 4 shows how the predictions are verified and the correction term K calculated. A variable FLAG is set equal to unity and a counting variable M is set equal to an integer variable FIRST, which was initialised to unity (step 21). The current time T is compared with PT(M) (step 22) and if PT(M) is greater than T, ie if it refers to some prediction which still lies in the future, FLAG is set to zero (step 23) and M is incremented (step 24). If M has not reached N (step 25) the computer returns to step 22 and compares the next PT(M) with T; otherwise N is incremented (step 26) and the computer returns to step 12 of Figure 3 and waits for the next sample time. If PT(M) was not greater than T, ie it refers to a prediction which should be currently being fulfilled or already

have been fulfilled, FLAG is examined (step 27). If FLAG is equal to unity FIRST is set equal to M+1 (step 28), but if FLAG is equal to zero an error warning is given (step 29). The meaning of FLAG is as follows. If FLAG is equal to unity none of the PT(M) which have been examined since step 21 was last passed refer to prediction times still lying in the future. If FLAG is equal to zero one or more PT(M) have been examined which do so refer. Thus if at step 27 FLAG is equal to unity the current PT(M) and all of the previously examined ones either relate to the present or the past, so on subsequent occasions they will all relate to the past. They do not therefore need to be examined on any subsequent occasions and FIRST is set to M+1 so that on subsequent occasions the first prediction to be examined is the first one which does not relate to the past. It may happen, if the wind speed varies particularly erratically, that one or more predictions still relating to the future are followed by a prediction relating to the present or the past. This would happen if the wind speed suddenly became shorter by more than one inter-sample period. This is what has happened if FLAG is equal to zero at step 27. The error warning at step 29 indicates that the wind has been erratic and some of the predictions will therefore be of doubtful reliability.

After step 28 or 29 T and PT(M) are once more compared (step 30) to determine whether they are equal, ie whether PT(M) relates to the present. The time T and the prediction times PT are expressed in units of the inter-sample period and are integers. Thus "the present" lasts for one inter-sample period in this program. If T and PT(M) are not equal (PT(M) relates to the past) the computer jumps to step 24 and increments M. Otherwise, if they are equal, the current value of the actual visibility AV as measured by the main visibility sensor 3 of Figure 1, is fetched from the appropriate computer 7 or 8 (step 31). From the difference AV-V(M) between the actual visibility and the uncorrected predicted visibility, the correction term K is updated (step 32) using the relation $K=E(AV-V(M)) + (1-E)K$ where E is a predetermined constant in the range $0<E\leqslant 1$. If E is equal to unity K is set equal to the difference AV-V(M) but if E is less than unity K is set equal to a weighted average of the current and previous differences AV-V(M). The correction term K is an empirical way of taking into account drifts in the calibration of the auxiliary sensors and fog formation and dispersal. If the general weather conditions are such that the fog is gradually clearing, as well as being blown about, then the uncorrected predictions will tend to underestimate the visibility. After a while K will be automatically adjusted to compensate for this. In a more elaborate system it would be possible to have sensors measuring, say, temperature and humidity, and hence, using known theoretical models of fog formation and dispersal, to predict formation and dispersal and apply a correction term based on the predictions rather than an ex post facto determination as in the present embodiment. The single additive correction term K is just the simplest form of correction to compute and apply.

After step 32 the actual visibility AV is compared with the corrected predicted visibility PV(M) (step 33) and if the difference is excessively large, according to a predetermined criterion, an error warning is given (step 34). The computer then jumps to step 24 and increments M.

Persons skilled in the computer programming art will have observed that in the program illustrated in Figures 3 and 4 the counting variables N and M increase without limit. Since only a limited number of V(N) PV(N) and PT(N) need to be stored at any time they can be stored cyclically, with V(L+N) being stored in the same location as V(N) for example, where L is a predetermined and sufficiently large integer.

The auxiliary sensors do not need to be point sensors. Transmissometers, or other known types of visibility sensors could be used.

Other variations will also be apparent to a person skilled in the art to which the invention relates. For example to determine and take account of the vertical structure of the fog sensors at two or more different heights could be provided.

WHAT WE CLAIM IS:

1. Apparatus at an airfield comprising:

a main visibility sensor arranged to monitor and to produce an output representing the visibility in a prediction area in the vicinity of the touchdown end of a runway;

one or more auxiliary visibility sensors arranged to monitor and to produce outputs representing the visibility in respective regions disposed about the prediction area;

wind sensors arranged to monitor and to produce respective outputs representing the wind velocity in the neighbourhood of the prediction area;

and computer means connected to receive the outputs of the main visibility sensor, the auxiliary visibility sensors and the wind sensors and arranged to derive therefrom predictions of the visibility in the prediction area;

the disposition of the visibility sensors being such that in the wind velocity monitored, their distances from the prediction area gives a prediction period substantially between five minutes and thirty minutes.

2. Apparatus as claimed in Claim 1 wherein there is a plurality of auxiliary visibility sensors which are disposed all around the prediction area.

3. Apparatus as claimed in Claim 1 or Claim 2 wherein there is a plurality of auxiliary visibility sensors and all the auxiliary visibility sensors are substantially equidistant from the prediction area.

4. Apparatus as claimed in Claim 1 or Claim 2 wherein there is a plurality of groups of auxiliary visibility sensors, each group consisting

of a plurality of sensors substantially equidistant from the prediction area, sensors in different groups being at different distances from the prediction area.

5. Apparatus as claimed in Claim 4 wherein the auxiliary visibility sensors are disposed in two concentric circles about the prediction area.

6. Apparatus as claimed in any of the preceding claims wherein the computer means is arranged to compare the predictions of the visibility in the prediction area with the actual visibility measured by the main visibility sensor, to derive therefrom a correction and to apply the correction to subsequent predictions.

7. Apparatus as claimed in any of the preceding claims wherein the sensors are disposed substantially as herein described with reference to Figure 1 of the accompanying drawings.

8. Apparatus as claimed in any of the preceding claims wherein the computer means is arranged to operate substantially as herein described with reference to Figures 3 and 4 of the accompanying drawings.

9. Apparatus substantially as herein described with reference to the accompanying drawings.

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1557183 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

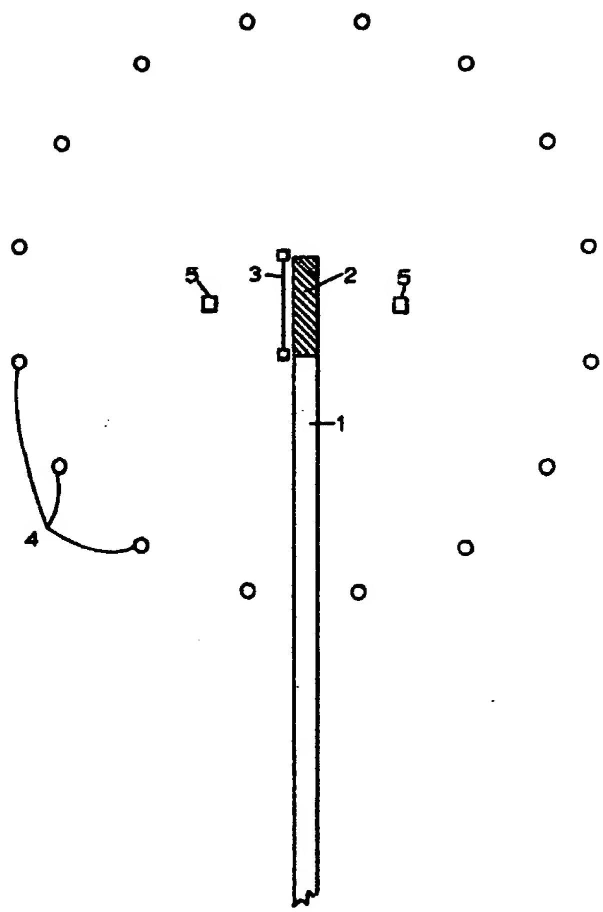

FIG. 1.

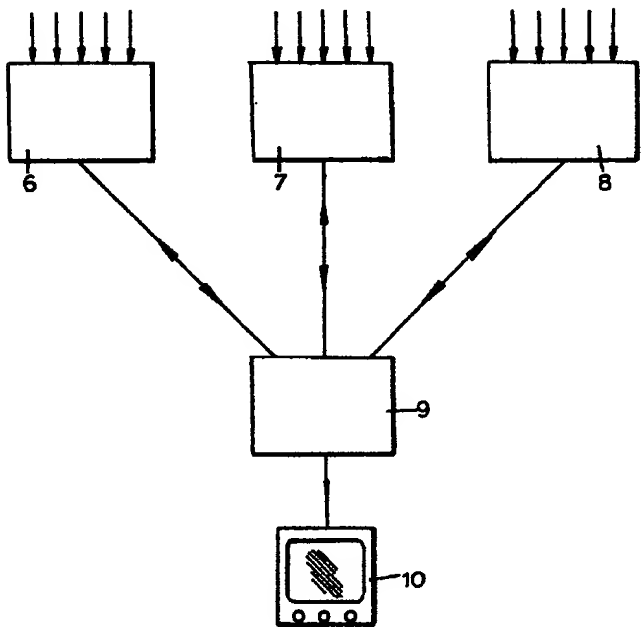

FIG. 2.

1557183 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

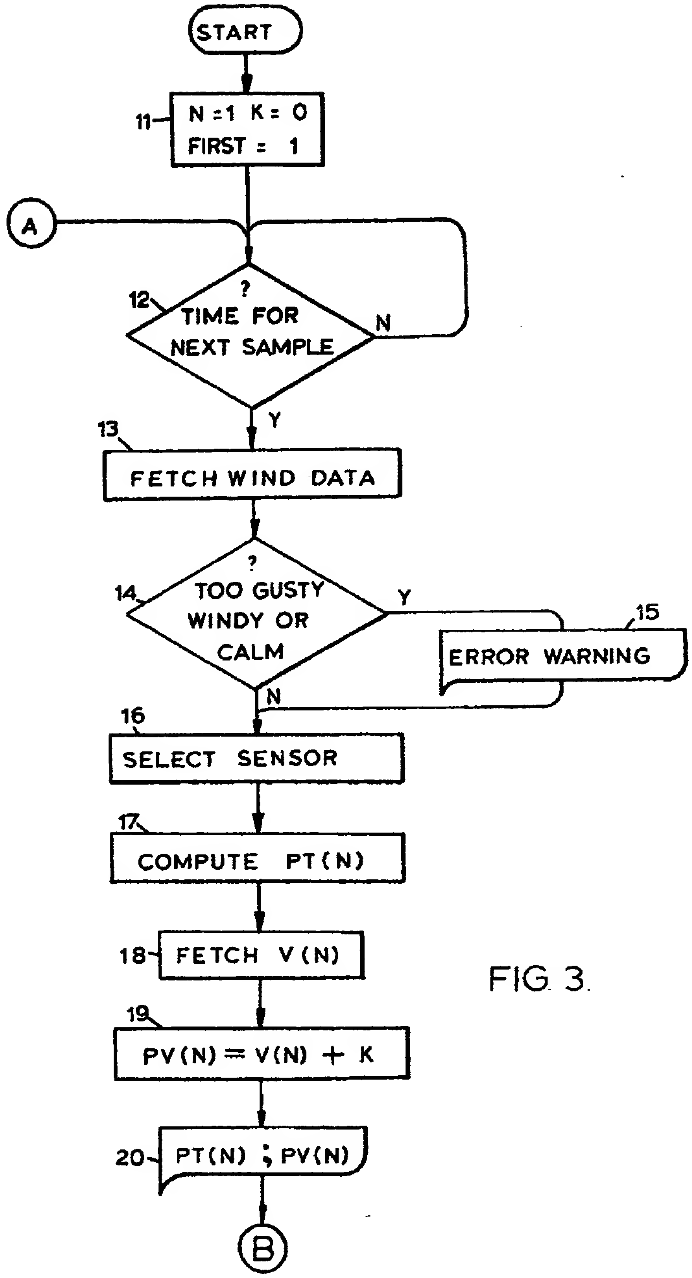

FIG. 3.